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DECONTAMINATION AND DOSE CONTROL MODELS: OPERATIONAL
CONCEPTS AND ESSENTIAL DESIGN ELEMENTS

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Menlo Park, California

February 1968

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Final Report

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DECONTAMINATION AND DOSE CONTROL MODELS

Prepared by:

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INTRODUCTION

The fate of an adequately sheltered population following a nuclear attack will depend upon their being prepared to initiate and sustain a long range recovery program. In the early stages of the postattack period, recovery operations will be directed toward the reactivation of facilities and services that are vital to survival. Any protracted delay in achieving this immediate goal could eventually lead to failure of the overall recovery program together with a wave of secondary fatalities.

The presence of fallout in sufficient amounts could cause unacceptable delays due to the threat of exposure to high residual radiation levels. However, past analyses of this problem have demonstrated that many serious fallout situations can be alleviated through a combination of adequate shelter protection followed by decontamination. Fallout removal, or the suppression of its effects, by the application of decontamination on either an area-wide or selected site basis can be used to decrease shelter stay times and to accelerate the reutilization of vital facilities. For this reason, decontamination (plus other less direct radiological countermeasures) is a key component of any postattack recovery program.

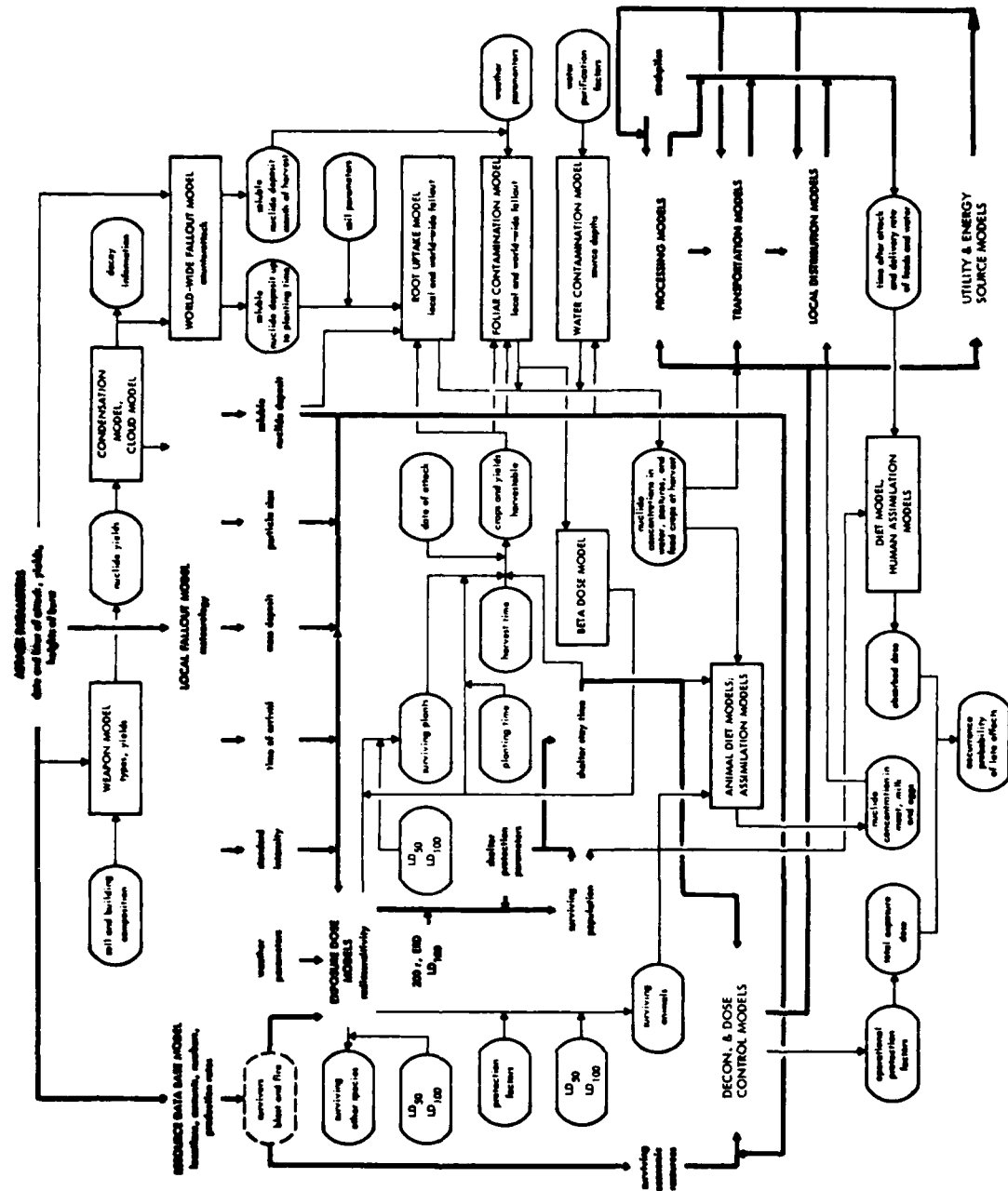
Background

Due to the importance of decontamination, one of the sets of countermeasure models included in the current development of a "recovery-model-system" is that of decontamination and dose control models.* The inclusion of dose control as an inherent part of decontamination modeling is essential to determining the feasibility of decontamination operations within the bounds of allowable dose criteria. The above requirement for D/DC models was first depicted by Miller¹ in a "schematic outline of model systems for estimating radiological effects." A retouched facsimile of this outline appears in Figure 1. The heavy lines serve to orient the D/DC models with respect to the local fallout model outputs and the economic recovery models. The latter, (a major subsystem of the recovery-model-system), shown grouped in the lower righthand quadrant of Figure 1, represents the recipients of the D/DC models output.

* Henceforth referred to as D/DC models.

Figure 1

SCHEMATIC OUTLINE OF MODEL SYSTEMS FOR ESTIMATING RADIOLOGICAL EFFECTS



Note that the D/DC models box was formerly called contamination-decontamination models in the schematic of Reference 1. Also, a box for utility and energy source models has been added to the original block of economic recovery models.

The recovery problem has been further clarified in a recent report by Clark and Miller² that provided an outline of the postattack recovery-model-system. A brief description was given of the individual models (and submodels) making up the system, and the functional relationships among the four major subsystems was established. The D/DC models were treated as part of the countermeasure models subsystems. However, the interactions among these countermeasure models were indicated in only a general way.

In addition to the foregoing problem-structuring and models-orientation process, considerable research effort has been devoted to projects contributing directly to the development of D/DC models. Over the years, a vast body of experimental data has been collected to measure the performance of decontamination methods and radiological recovery (Rad/Rec) operations. Meanwhile, postattack research has investigated the areas of radiological defense (RADEF) planning,³ radiological target analysis,⁴ decontamination scheduling analysis,⁵ and decontamination dosage analysis.^{4,5,6} Based on the findings of this research,* as well as the status of other essential inputs required, the development of D/DC models is now considered feasible.

The primary purposes of the D/DC models are to define and describe the technical parameters associated with various individual postattack Rad/Rec operations and procedures and to estimate the effectiveness and effort required to implement an appropriate set of Rad/Rec countermeasures. The models must therefore provide methods for estimating the amounts of resources that would be consumed during the performance of Rad/Rec operations in relation to those postattack environments in which the countermeasures are both applicable and required.

Project Objective

The stated objective of this research is to develop a set of decontamination and dose control models (including the required mathematical descriptions) that are capable of estimating the cost and effectiveness of large-scale radiological recovery operations in the postattack period;

* A great deal of related work also has been reported in References 7, 8 and 9.

where cost refers to the resources needed for decontamination plus their rates of consumption, and effectiveness refers to the degree and rate of operational achievement, including the improvement in the radiological environment.

Approach and Coverage

Fulfillment of the above objective depends on the successful completion of several distinct but related tasks. Flow diagrams and network descriptions of the D/DC models are constructed to establish the major interactions with the various elements of the overall recovery-model-system and with those systems that provide input or receive output. Elements of the recovery-model-system linked with the D/DC networks are defined to ensure compatibility and consistency among the model systems and to incorporate practical model constraints in terms of the Rad/Rec problems. Subsystem and subelement networks, such as the target analysis and decontamination scheduling submodels, are to be developed as required. Necessary mathematical descriptions of the operations represented by the various elements of the D/DC models will be written for the purpose of estimating the effects of attack conditions on system input and output parameters.

This report outlines the D/DC models in terms of the inputs, outputs, and internal functions involved and orients the D/DC models with respect to the rest of the recovery-model-system. The status of the sources (or models) of the critical input information and data is discussed, and the magnitudes and ranges of input parameters are given. Comparable descriptions of the anticipated outputs and subsystems, together with the controlling parameters, are included.

A following report will cover the development of a procedural planning subsystem composed of the target analysis and decontamination scheduling submodels. The computational techniques for these two submodels will be organized and formalized into a set of basic elemental operations which, when performed in the proper sequence, will generate the Rad/Rec procedures required to produce the desired cost/effectiveness outputs.

SOME PERTINENT ELEMENTS OF THE RECOVERY MODEL SYSTEM

General Relationships

Before proceeding with the development of the D/DC models, it is first necessary to give consideration to the orientation of these models within the framework of the overall recovery-model-system. Reference 2 was cited earlier as having already outlined this system. Figure 2, which was derived from the same source, shows the functional relationships among the four subsystems (or types) of models describing the recovery-model-system. Three subsystems are indicated by the weapon effects, economic systems, and countermeasure models (where the latter subsystem includes the D/DC models). The fourth subsystem, civil defense organizational models, is comprised of the recovery requirements, recovery planning, and recovery management models.

Countermeasure Subsystem

With the exception of the countermeasure models, it is beyond the scope of this project to delve further into the intricacies of the recovery-model-system other than to explain those links that directly effect the D/DC models. It is important to an understanding of the problem to make a cursory examination of the countermeasure model subsystem shown in Figure 2.

Figure 3 contains a flow diagram of the six models basic to the countermeasure subsystem. Three of the models, debris clearance, D/DC, and damage repair and salvage are closely related in purpose and design. They are operationally oriented such that the output from (or the requirements of) any one model may have a definite effect upon the other two. For a given attack situation, it is not possible to predict which of the three recovery operations represented would have precedence--without first assessing the joint output of the corresponding countermeasure models via the recovery planning model. It is even conceivable that debris clearance, decontamination, and repair and salvage operations could be carried out simultaneously. In any case, these countermeasure operations will be competing for the available resources allocated to the overall recovery effort. For these reasons, the three operational countermeasure models are shown to function at a comparable level, as indicated by the continuous loop connecting them.

Figure 2

FUNCTIONAL RELATIONSHIPS AMONG RECOVERY SUBSYSTEM AND MODELS.

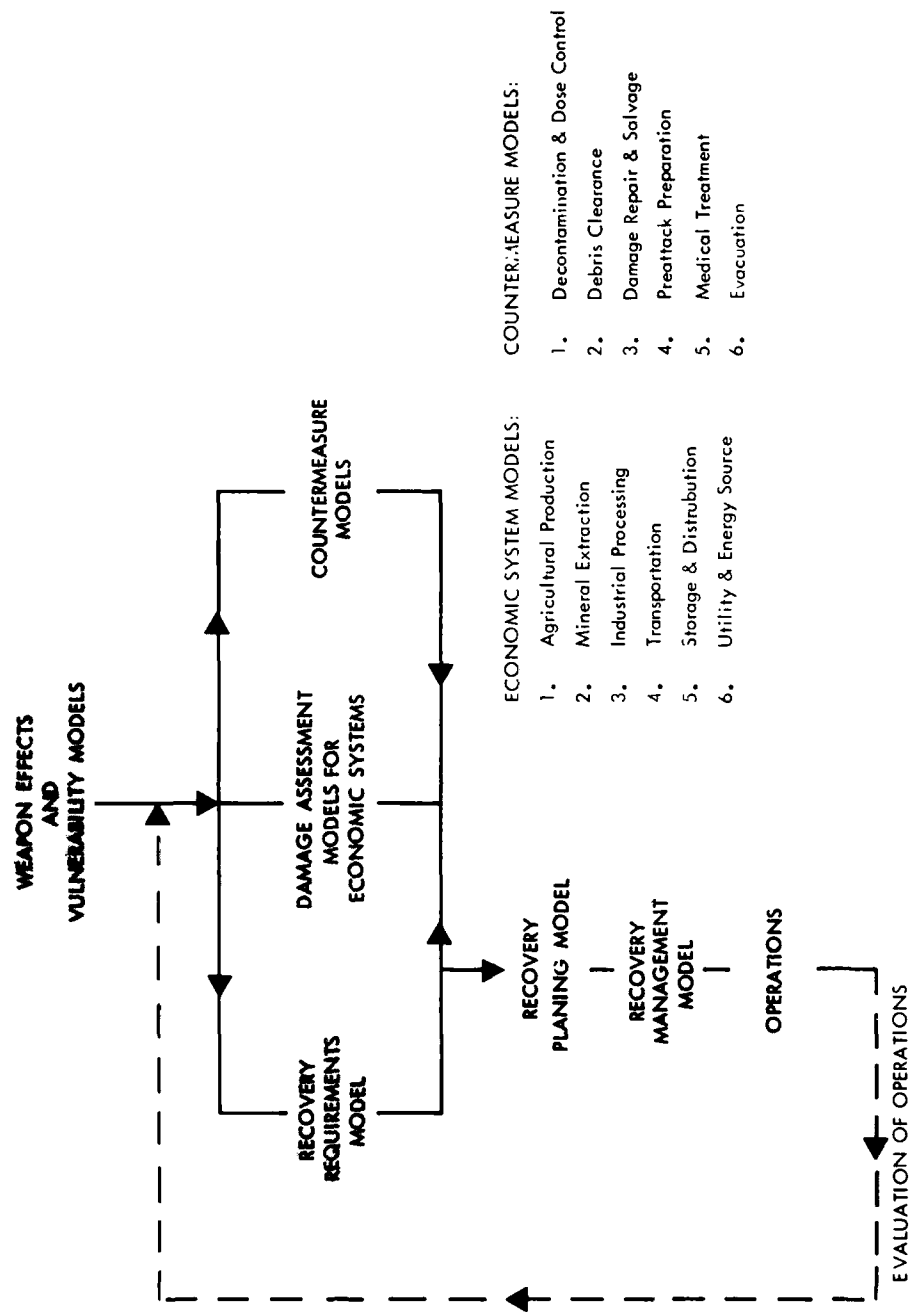
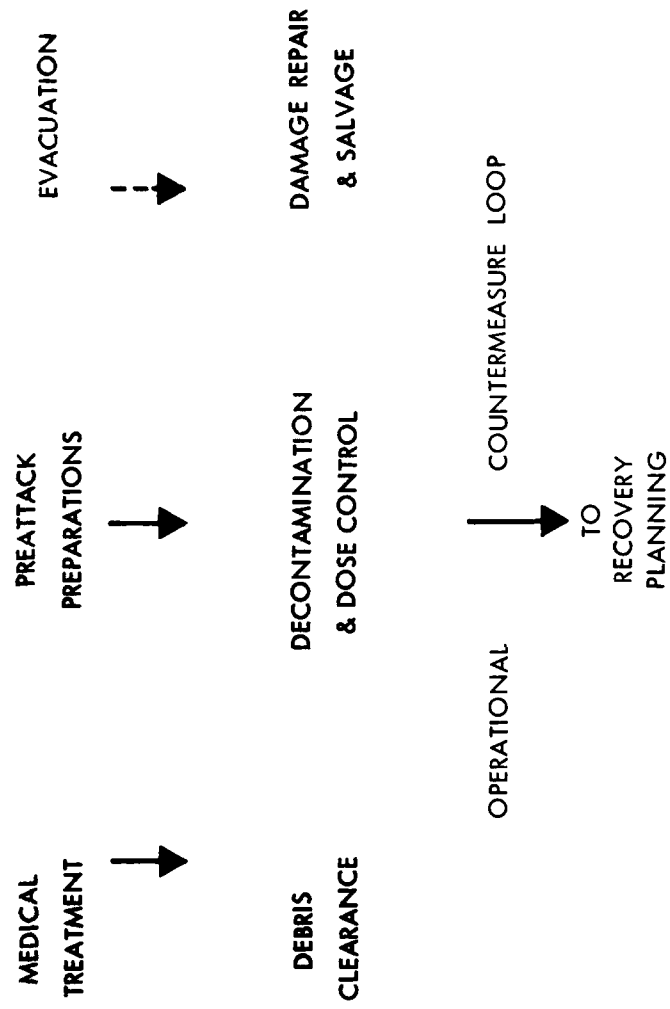


Figure 3

THE COUNTERMEASURE MODELS SUBSYSTEM



The three models appearing across the top of the diagram in Figure 3 act as independent sources of input to the operational countermeasure loop. The evacuation model, which is set off in the flow diagram by broken lines, must be considered from still another standpoint. As a source of input, evacuation can only be from communities and installations outside the recoverable target area. A totally different situation (not covered by Figure 3) results if the target area is to be evacuated instead. Under these circumstances, resources* evacuation becomes a negative alternative to the more positive recovery actions indicated by the operational countermeasure loop. Both aspects of the resources evacuation models must be taken into account by recovery planning.

The effects of medical treatment models and the approaches used are fairly straightforward and will not be discussed here. Some special applications of preattack preparations models peculiar to radiological recovery operations are covered in a later section.

* Includes human and material resources.

DECONTAMINATION AND DOSE CONTROL MODELS DESCRIPTION

Basic Assumptions and Requirements

The main purpose of the D/DC models is to provide a means for estimating the cost and effectiveness of postattack Rad/Rec operations involving vital target complexes. This implies that, following attack, a command decision will be made concerning the desirability and time of need for reactivating specific areas and installations. In addition to the decision input, D/DC model development assumes the existence of input data affecting two general sectors of interest, i.e., environmental conditions and radiological countermeasure applications.

A cursory investigation of the problem indicates that, to accomplish the stated goal, the D/DC models will be required to perform three basic functions. Chronologically they are:

1. Evaluate the radiological situation in light of the furnished inputs
2. Generate operational recovery procedures based on the findings in (1)
3. Assess and compare the cost and effectiveness data derived from the operations described in (2)

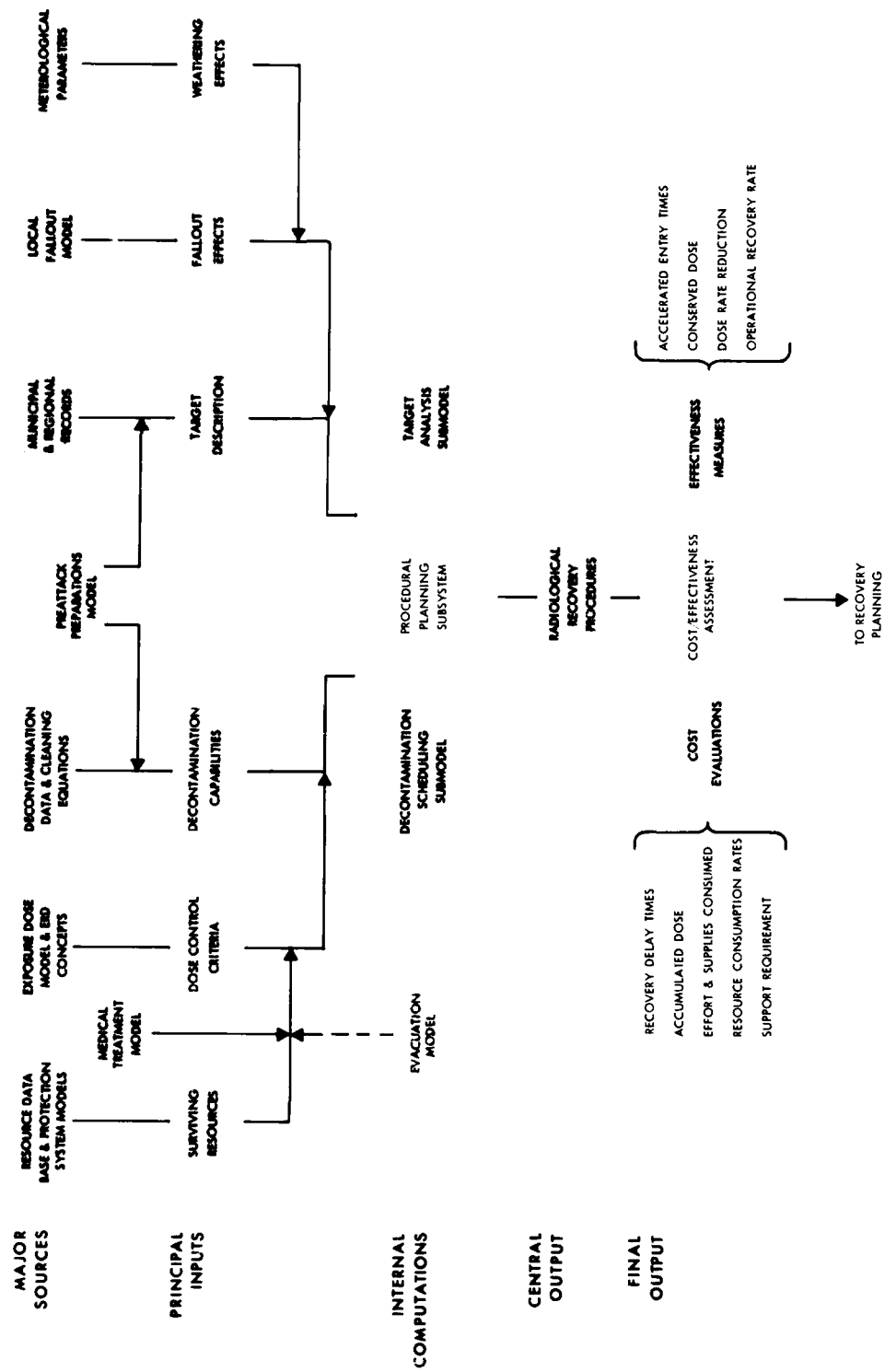
The D/DC models output from step 3, together with outputs from the other countermeasure models, will be used by the recovery-model-system to determine the extent and rate that the production capacity represented by the economic system models (refer to Figure 2) could be regained.

A D/DC Model System

The general outline of a D/DC model system is shown in the flow diagram of Figure 4. The natural division of the essential elements of the model system according to its functional stages is indicated by the labels appearing down the left side of the diagram. Note that rectangular boxes are used to enclose modeled elements. Boxes that have their corners removed contain input sources not yet classed as models. System inputs and outputs are set off by ellipses.

Figure 4

DECONTAMINATION AND DOSE CONTROL MODEL SYSTEM



Starting with an assumed weapon attack situation, the principal inputs to the model system are supplied by the six major sources spread across the top of Figure 4. The left bank of sources and inputs furnishes data for determining the operational applications of radiological countermeasures--as required primarily by the decontamination scheduling submodel. The right bank of sources and inputs contributes information describing the environmental conditions--as required by the target analysis submodel.

A seventh source of input, the preattack preparation model, can influence both operational and environmental considerations. As shown by the flow diagram, decontamination capabilities and target description inputs are especially susceptible to preattack preparations. The possible contributions of two other countermeasure models to the status of surviving resources (material and human) are also indicated. However, the medical treatment and evacuation models have not been developed beyond the early definitive stage given in Reference 2. Any D/DC model system inputs attributed to these two countermeasure models must necessarily be limited to estimated ranges of values.

The decontamination scheduling and target analysis submodels combine to form the heart of the D/DC model system. Together, these two submodels contain the planning function from which the central outputs, i.e., feasible Rad/Rec procedures, are generated. Although the decontamination scheduling and target analysis submodels are shown in Figure 4 to initially depend upon operational and environmental types of input data, respectively, the actual processing of this information and the corresponding production of internal outputs within the subsystem rely upon cross-feeding of the results between submodels. This interexchange is indicated in the flow diagram by the loop connecting the decontamination scheduling and the target analysis models which, admittedly, is an oversimplification of the actual network making up the procedural planning subsystem.

In order to derive the final cost and effectiveness outputs from the D/DC model system, schedules of Rad/Rec operations first must be obtained as a direct consequence of the procedural planning subsystem. These schedules will give equipment and supply allocations, personnel assignments, sequence and timing of decontamination operations, and operator and team dosage charges. The detailed description of the predicted application of radiological countermeasures contained in this central output can then be assessed in terms of the resources consumed and the recovery status achieved. This assessment will consist mainly of summations and comparisons of specific cost and effectiveness output parameters. A number of these parameters are shown in brackets at the

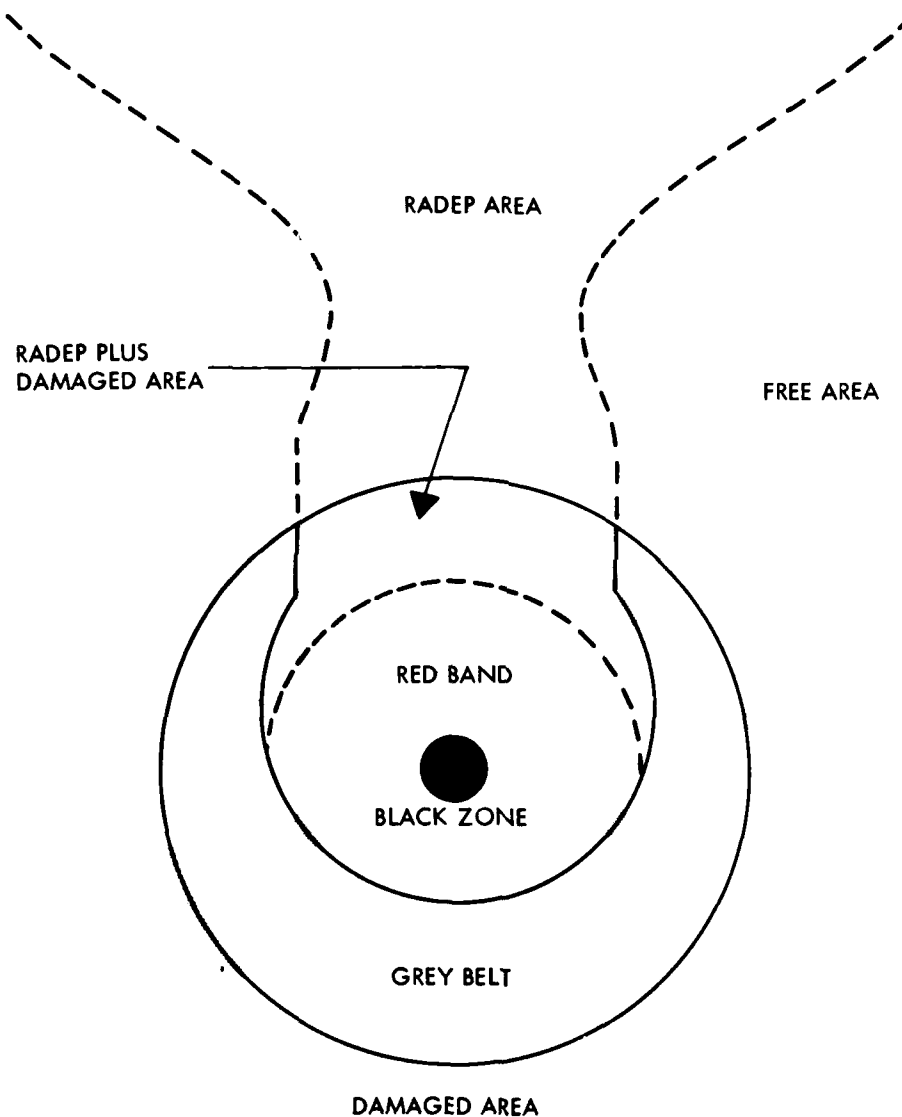
bottom of Figure 4 opposite the cost/effectiveness assessment loop. The resultant outputs (both final and central) of the D/DC model system will generally serve as inputs to, or restraints on, other models of the recovery-model-system, especially the recovery planning model (see Figure 2).

In a strict sense, the foregoing outline of a D/DC model system is limited to recovery of the RADEP (radioactive deposit) area situated downwind from the circular region of fire and blast damage. This restriction can be lifted by the addition of the debris clearance and damage repair and salvage models mentioned in Section II. Any contribution from these two countermeasure models implies that Rad/Rec operations may extend into that portion of the damaged region that is contaminated by fallout. Figure 5, which appeared originally in Volume II of Reference 10, shows this portion to lie between the RADEP area and the Red Band, the latter being a region of extensive physical damage and high radiation intensities.

Insofar as the D/DC model system flow diagram is concerned, the debris clearance and damage repair and salvage models may be envisioned as sharing the same links that couple the preattack preparations model with the input network. This means that each of these countermeasure models can, in its own way, alter the decontamination capabilities and target description inputs to the D/DC model system. Because the design of neither model has been completed, anticipated inputs from debris clearance and damage repair and salvage contributions must be based on estimated ranges of values. Therefore, the current development of a D/DC model system will consider the recovery of only those undamaged targets in the RADEP area.

Figure 5

APPROXIMATE PROPORTIONS OF COUNTERMEASURE ACTION AREAS FOR
AN MT YIELD LAND-SURFACE DETONATION (50 PERCENT FISSION)



STATUS OF ESSENTIAL ELEMENTS

The discussion thus far has provided a general description of a D/DC model system in terms of the functional relationships among the main divisions of essential elements. The purpose of this section is to present the current status of the elements themselves, including inputs and sources, desired outputs, subsystems and submodels, and estimates of the magnitudes and ranges of the pertinent parameters involved.

Principal Inputs and Sources

The flow diagram in Figure 4 gives the six principal kinds of input information required by the D/DC model system. Three of these--target description, fallout effects, and weathering effects--provide the environmental data instrumental to target analysis. The target description input, as the name implies, describes the geometrical and structural characteristics of target complexes. This includes both the general delineation of large buildup target areas with their components and the more detailed description of pertinent component properties.

The most probable source of data will be from governmental records--municipal, county, state, and regional. For instance, the size, configuration, and orientation of target components and surfaces can be found from maps, drawings, and aerial photographs for the purpose of calculating the relative exposure-rate contribution factors required by the target analysis model. The mass thickness of structural members (for making shielding calculations) can be estimated from engineering drawings and construction specifications. Photographs, drawings, topographical surveys, maps, and preattack on site inspections all may be required to reveal surface characteristics important to both target analysis and decontamination performance.

Some of the kinds of data describing surface properties affecting the performance of various decontamination methods are listed below:

1. Type of material--earth, concrete, wood, metal, etc.
2. Physical condition--new, intact, and well-kept or old, weathered, and in disrepair
3. Surface texture--smooth, troweled, bladed, and free of seams and joints; or rough, graveled, shingled, tilled, and interrupted by seams and joints

4. Drainage features--slope, crown, gutters, catch basins, etc.

The fallout effects input extends the target description to include a definition of the radiological environment. Required data are given in terms of (1) the extent of contamination according to predicted fallout patterns, (2) fallout arrival times, (3) standard exposure dose rates (r/hr at one hour after detonation), (4) mass concentration of fallout, (5) particle size range and distribution, and (6) net decay rate of radioactive nuclides.

These fallout properties and effects are directly obtainable from the local fallout model depicted in Figure 2. The basic concepts of the local fallout model are explained in Reference 1, and numerical methods for its application are given in Reference 10. A compilation of standard dose rates, mass loadings, and particle sizes are contained in Reference 11 for a wide range of weapon yields and downwind distances.

The weathering effects input offers a further refinement to the target description by providing a means for estimating changes in the radiological environment caused by the migration and redistribution of fallout deposits under the action of the natural elements--as distinguished from the movement of fallout material due to decontamination measures. Unfortunately these changes (either in mass loading or radiation level) must necessarily be limited to rough approximations, since the correlation between uniform fallout deposits and their reaction to weathering is not well established. Aside from some qualitative observations from the Costa Rican operations,^{12,13} the rather gross measurements obtained from the target complex experiments^{14,15} constitute the sole data source.

This information is restricted to temperate climate conditions which include the effects of wind (and, to a lesser degree, the effects of light rain) on the movement of fallout particles and the resulting reduction in observed radiation levels. No comparable data are available for the effects of snow or other cold weather conditions, except for their influence on certain decontamination procedures. Where cold weather conditions are expected, the possible reduction in radiation intensity by the shielding of fallout that is buried or mixed in snow and ice must also be taken into account--in addition to any changes in the location of fallout deposits.

The meteorological parameters required for inputs cover the customary conditions of wind velocity, temperature, and precipitation. Records of the climatic history of a particular locale should provide the necessary data, including the seasonal variations in these variables.

The three remaining principal inputs shown in Figure 4--decontamination capabilities, dose control criteria, and surviving resources--provide the operational data needed for the preparation of decontamination schedules. The decontamination capabilities input indicates the performance of various fallout removal methods and equipment for an assortment of target surfaces and fallout deposit levels. Decontamination experiments and cleaning equations derived from basic decontamination theory are the major sources of input data.

The prime indicator of performance is the decontamination effectiveness--which is customarily defined as the fraction of the original fallout (or radiation) level remaining after decontamination is terminated. Experimental effectiveness values have been collected for several method-surface combinations. A complete compilation of effectiveness values obtained under both temperate and cold climatic conditions is presented in Reference 16, together with the influencing environmental and operational factors.

For many method-surface combinations, effectiveness improves with the increased expenditure of decontamination effort. In these instances, the cleaning equations are used to determine the rate of improvement or method efficiency. Depending upon the method and equipment employed, three equations are currently in use:

$$F = F^* + (1 - F^*) e^{-Kp} \quad (1)$$

for mechanized sweeping of pavement or firehosing of roofs and pavement with standard fire nozzles,

$$F = F^* + (1 - F^*) e^{-3K_0 p^{1/3}} \quad (2)$$

for mechanized flushing or firehosing of pavement with nozzles delivering a flat fan-shaped water jet, and

$$F = e^{-Kp} \quad (3)$$

for surface removal methods like scraping, grading, and bulldozing land areas where

F is the decontamination effectiveness value,
 F* is the lower limit of F that is theoretically achievable
 after a large number of decontamination passes,
 K and 3K₀ are the decontamination efficiency coefficients, and
 p is the number of decontamination passes.

The decontamination theory, cleaning equation development, and estimates of equation coefficients for various candidate methods are presented in Volume II of Reference 10. The resultant efficiency curves described by Equations (1), (2), and (3) demonstrate the effects of working rate (or forward speed), decontamination effort expended (or number of decontamination passes made), fallout mass loading, and fallout particle size range on the reduction of fallout concentrations and associated radiation levels.

In addition to the above required input information, References 10 and 16 contain related operational information for determining manpower and equipment requirements and for estimating the consumption of supplies. The recommended usage of decontamination tools and equipment for safe and efficient operation is also documented in these and supporting references.

It should be pointed out that not all decontamination methods have been tested to the same degree of detail. With the possible exception of firehosing of paved areas, the performance of no method has been tested using the entire range of fallout mass loadings and particle sizes that could result in a nuclear war. Some methods have been tested using only one mass loading and one particle size range. This is particularly true of most of the results from the cold weather experiments.¹⁶ In some cases, where extrapolations of the data are possible, the cleaning equations provide a means for estimating decontamination method performance for untested conditions.

The dose control criteria input is a boundary condition for testing the feasibility of decontamination. The equation for total dose is combined with that for the effective residual dose (ERD) to determine the technical* feasibility of a particular RADEF system. If the total exposure dose to decontamination crews (or mission personnel) in a given situation does not exceed an allowable dose limit, D^* , the RADEF system and especially the decontamination operation are considered feasible.* Where the biological repair of radiation damage is taken into account, D^* is set equal to 200 r ERD(max). When this limit is converted to total dose, the D^* values closely approximating 200 r ERD(max) are 190 r in one week, 270 r in one month, and 700 r in one year³.

* Where adequate resources are available, operational feasibility is determined.

From the gamma exposure dose model, the general equation³ of total dose for standard operations such as decontamination is

$$D^* \geq RN_1 I^0 \Delta DRM_1 + RN_2 I^0 \Delta DRM_2 + RN_3 I^0 \Delta DRM_3 \quad (4)$$

where RN represents the residual number which is defined as the ratio of actual dose to potential dose for a given exposure period, I^0 represents the standard exposure dose rate in r/hr at one hour, and ΔDRM represents the difference in dose rate multipliers and is used to estimate potential exposure dose. The subscripts refer to the three exposure periods characterizing a RADEF system: (1) the shelter period, (2) the recovery (decontamination) period, and (3) the target reutilization period.

Some typical residual numbers have been determined for all three exposure periods from experimental data and theoretical considerations of structural shielding, target configuration, and contributions from the collections of fallout material during decontamination operations.^{4,14,15} For any proposed RADEF system, the target analysis submodel contains the necessary equations for computing suitable residual numbers as part of the internal output from the procedural planning subsystem. Dose rate multipliers have been derived from Miller's decay curve^{3,10} and are shown in the curves of Figure 6.

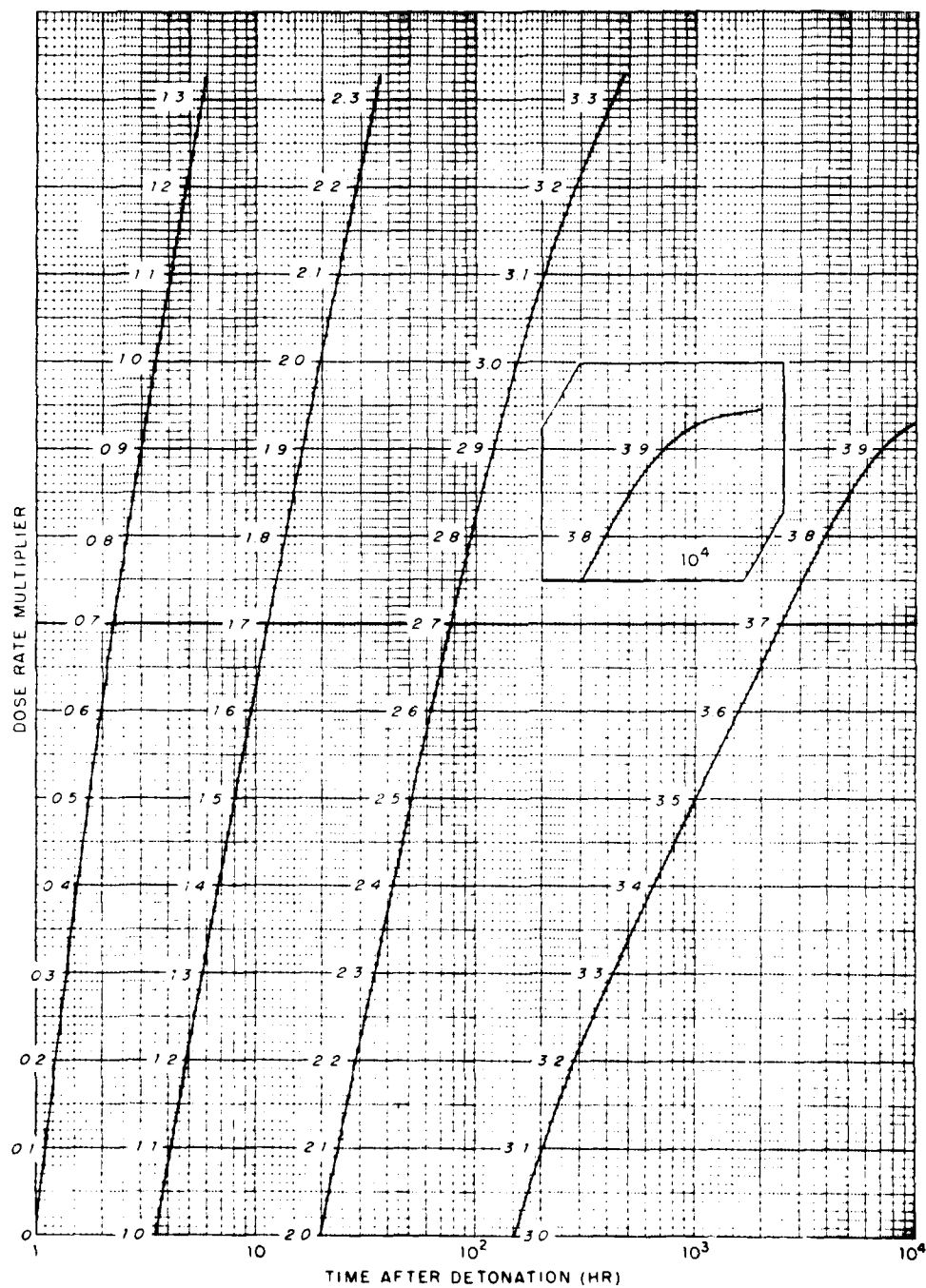
The surviving resources input refers to both the human and material resources available for implementing Rad/Rec procedures. Ideally, estimates of resources would be made from information furnished by the resources data base model indicated in Figure 1 and the weapon vulnerability models indicated in Figure 2. The vulnerability models have not been developed and current resource models either do not generate data in a form applicable to the needs of the D/DC model or their output is not conveniently available. For these reasons it will be necessary to postulate a set of starting conditions (including certain attack parameters) from which reasonable estimates of surviving resources may be derived.

For instance, estimates of the number of able-bodied persons surviving a particular attack will depend upon assumed distributions of population versus shelter spaces and protection factors. From this information the amount of surviving dose resource available for recovery can be calculated. Histories of the preattack occupations of the population will provide the means for predicting surviving skills as well.

In a similar way, estimates of the surviving material resources required in Rad/Rec procedures may be made. These will be based on

Figure 6

DOSE RATE MULTIPLIER CURVES



descriptions of assumed stockpiles, production capabilities, and pre-attack protective measures and their degradation from attack effects. Survival estimates for utilities and delivery services (especially water) must also be included.

In addition to the six principal inputs and their major sources described above, a seventh source of input is represented by the pre-attack preparation model. As indicated by the flow diagram of Figure 4, this model is a potential source for both the operational and environmental data required by the procedural planning subsystem. Although no preattack preparations model* exists, its output requirements are fairly well defined with respect to the advance preparation of fallout-target surfaces for decontamination operations.

These requirements have been organized in Reference 17 into a series of recommendations for improving the contamination-decontamination characteristics of target components and surfaces. Special consideration has been given to five specific problem areas. They are:

1. Improved surface systems--configuration and texture
2. Accessibility of target surfaces--roof and ground levels
3. Proper drainage--under condition of inclement weather or wet decontamination operations
4. Adequate water storage and services
5. Soil conditioning and stabilization

The above information is largely qualitative. However, it includes a number of common sense suggestions whose observance will reduce surface contaminability, facilitate decontamination, and improve waste disposal.

Procedural Planning Subsystem

As indicated by Figure 4, all the input information passes into the procedural planning subsystem which consists of two submodels--one for target analysis and one for decontamination scheduling. Although these submodels are interdependent, each is expected to perform certain definite functions. Insofar as the D/DC model system is concerned, the target analysis submodel contains the functions for estimating the residual numbers required by the expression for exposure dose given in

* A broad definition is given in Reference 2 which refers to the stockpiling, hardening, and dispersing of critical material resources.

Equation (4). The decontamination scheduling submodel, as the name implies, contains the functions for computing the schedules of recovery operations within the limits of available resources and capabilities.

In estimating appropriate residual numbers, the target analysis procedures essentially consist of functions for calculating the relative radiation intensities within a target complex. The technique employed takes into account the influence of (1) geometrical and structural features of target components, (2) fallout distribution, and (3) recovery operations. Specific operations include the estimating of the mass thickness of building elements, the effectiveness of the recovery effort, the exposure rate contribution factors, the decontamination equipment shielding, the exposure rates from redistributed sources, and the attenuation and scattering effects on the exposure rates from all sources.

In the decontamination scheduling submodel specific operations include the estimating of operational requirements for manpower, equipment, supplies, and time. Because of the exposure dose limit (boundary condition), exposure doses in shelter (i.e., shelter adequacy), available post shelter exposure doses, and rate of dose accumulation are also included. In addition, decontamination scheduling deals with such quantities as decontamination method effectiveness, specific effort, working rate, team size, work shift length, shelter distributions, dose time intensity relations, and other similar factors. The feasible operational schedules from the systematic consideration of all these factors are only those for which the recovery effort may be carried out within specific limits of available dose, as well as of available material resources and human skills.

The latest techniques for carrying out target analysis and decontamination scheduling are described in References 4 and 5, respectively. These techniques are considered appropriate for the two submodels required. However, for the purposes of the D/DC model system, target analysis and decontamination scheduling functions have yet to be integrated into a fully operable procedural planning subsystem model.

Model Outputs

There are three types of outputs from the D/DC model system--central, final, and internal. The central output refers to the Rad/Rec procedure produced by the procedural planning subsystem. It is characterized by organizational and operational schedules giving the sequence and timing of various decontamination methods and procedures, the personnel assignments, the equipment and supply allocations, and the estimated operator or crew exposure doses.

The final output consists of the cost/effectiveness assessment of the central output. As shown in the D/DC model flow diagram, the assessment is given in terms of a number of specific final output parameters (see Figure 4). Thus, the various effectiveness measures and cost evaluations must be weighed against each other to determine the best of the feasible Rad/Rec procedures.

This final output data, together with the comparable output from the other countermeasure models (see Figure 3), may be used as inputs to or restraints on other system models* for evaluating the influence of the countermeasures on the rate at which the production from other systems† could be recovered during the postattack period. The output also may be used directly and independently in the planning of RADEF operations.

The internal output refers to those basic factors and equation coefficients that must be derived in the course of the procedural planning computations. These outputs include such quantities as contribution factors, attenuation factors, residual numbers, and decontamination method effectiveness. All are required in achieving the central output of the D/DC model system.

Pertinent Parameters

Past contributions of postattack research have made possible the identification of parameters pertinent to the D/DC model system. Many parameters have been evaluated through experimental measurements and/or models and their ranges of applicable values have been established. These are presented in the tabular outline that follows. A number of parameters not conveniently identified in terms of physical units also are included to complete the outline. Some of these have been mentioned earlier in the text.

* Such as the recovery planning, recovery management, and recovery requirements models of Figure 2.

† Namely, the economic systems listed in Figure 2.

Input Parameter Table

I. For Environmental Conditions

A. Fallout properties and effects from the local fallout model

1. Standard dose rates: 3000 to 100,000 r/hr
2. Mass loading: 1 to 500 g/ft²
3. Particle diameter: 30 to 4,000 microns
4. Fallout arrival times: 1 to 24 hrs
5. Fallout solubility: in percent retention of contributing nuclides
6. Decay rates: as contained in dose rate multiplier curves (see Figure 6)
7. Extent of contamination: according to fallout pattern dose and/or dose rate contours

B. Target description from maps, drawing, photographs, construction specifications, and on-site inspections

1. Size, configuration, and orientation of target components and surfaces
2. Structural mass thickness: 1 to 180 lb/ft²
3. Surface characteristics:
 - a. type of material
 - b. physical condition
 - c. drainage features
 - d. surface texture--
terrain roughness factor: 0.5 to 1.0

C. Weathering effects--dose rate reduction by natural removal or redistribution of fallout

1. For maximum wind velocities of 10 to 30 knots:
 - a. planted, tilled or graveled surfaces--
residual fraction: 0.8 to 1.0
 - b. flat roofs, pavement, or relatively smooth ground (no vegetation)--
residual fraction: 0.1 to 0.6

2. For light rain (<1.0 in./wk) and light winds (<10 knots):

paved surfaces and flat roofs--
residual fraction: 0.7 to 1.0

3. For heavy rain (0.15 to 0.2 inches in 30 min.):

sloped metal roofs only--
residual fraction: < 0.01

II. For Operational Applications

A. Decontamination capabilities from experimental data

1. Working rates: 180 to 254,000 ft²/hr
2. Recovery effort--
 - a. absolute effort: 1 to 3 passes
 - b. specific effort: 6×10^{-6} to 3.6×10^{-3} equip-hr/ft²
3. Decontamination effectiveness, first pass only--
residual fraction: 0.01 to 0.5
4. Manpower and equipment requirements per method
5. Consumption of supplies--
 - a. fuel: 5 to 15 gal/hr/engine
 - b. water: 0.068 to 3.3 ga'/ft²

B. Surviving resources from distributions of population, stockpiles, production capabilities, and protection systems

1. Human resources: skills and available dose
2. Material and economic resources: decontamination equipment and supplies

C. Dose control criteria from exposure dose model

1. Total dose and ERD concepts
2. 200 r ERD(max) dose limits:
 - a. 190 r/wk
 - b. 270 r/mo
 - c. 700 r/yr

III. Preattack Preparations--Environmental and Operational Inputs

A. Reduced contaminability--by improved surface systems

B. Facilitation of decontamination

1. Proper drainage--

minimum slope: 1 to 4%

2. Accessibility of surfaces

3. Adequate water storage and services

4. Soil conditioning and stabilization

C. Waste disposal capabilities

1. Sewer and storm drain capacity

2. Gutter and ditch design

3. Frequency of collection points

SUMMARY

Through the use of flow charts and schematic diagrams the concept of D/DC models has been described and oriented with respect to the principal components making up an overall recovery model system. The D/DC model was shown to belong to a subsystem consisting of six inter-related countermeasure models. The functional relationships among this countermeasure subsystem and the three additional subsystems required to complete a workable recovery model system were also indicated.

A simplified flow diagram of a D/DC model system was constructed to show the essential model elements and the interconnecting paths required for handling the input and output information. The flow diagram demonstrated how the D/DC model system can be used to evaluate radio-logical situations, generate Rad/Rec procedures, and provide the cost and effectiveness data.

The status of the principal environmental and operational inputs and sources was discussed, pertinent input parameters were identified and the range of their values was summarized. The computations and operations of the required subsystems and submodels were indicated, and the content of the internal, central and final outputs of the D/DC model system was indicated.

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DECONTAMINATION AND DOSE CONTROL MODELS:

Operational Concepts And Essential Design Elements

By: W. Leigh Owen
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DETACHABLE SUMMARY

The continued survival of persons emerging from shelter following a contaminating nuclear attack depends on their capability to plan and carry out a sustained recovery effort. Because the presence of fallout could cause unacceptable delays in initiating such an effort, decontamination becomes a critical part of postattack recovery plans and operations. For this reason, SRI's current recovery model development program includes the requirement for a decontamination and dose control (D/DC) model system. The stated objective of this research is to develop a set of D/DC models (including the required mathematical descriptions) that are capable of estimating the cost and effectiveness of large-scale radiological recovery operations in the postattack period. This first report describes the concept of the D/DC models in terms of the inputs, outputs, and internal functions involved and orients the D/DC models with respect to the principal components of the recovery model system.

Through the use of flow charts D/DC models are shown to be one of a set of six distinctly different but interrelated countermeasure subsystems, which, together with the three subsystems of weapons effects, economic systems, and civil defense organizational models, constitute

the overall recovery model system. The functional relationships among these subsystems and among the models of the countermeasure subsystem are indicated.

A general outline of a D/DC model system is charted to show the essential model elements and the interconnecting paths required for handling the input and output information. The flow chart demonstrates how the D/DC model system can be used to evaluate radiological situations, generate radiological recovery procedures, and provide cost and effectiveness data. The importance of the target analysis and decontamination submodels to the D/DC model design is stressed.

The status of the principal environmental and operational inputs and sources are discussed, pertinent input parameters are identified, and the ranges of their values are summarized. The computations and operations of the required subsystems and submodels are indicated, as are the contents of the internal, central, and final outputs of the D/DC model system.

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13. ABSTRACT The concept of decontamination and dose control (D/DC) models is described and oriented with respect to the primary components of an overall recovery model system. Because D/DC models belong to the countermeasure models subsystem, the interacting roles among countermeasure models are presented. Functional relationships among the countermeasure subsystem and other subsystems required to define a workable recovery model system are indicated. A general outline of a D/DC model system reveals the essential model elements and demonstrates that the D/DC model is expected to evaluate radiological situations, generate radiological recovery procedures, and provide cost and effectiveness data. The status of the principal environmental and operational inputs and sources is discussed, pertinent input parameters are identified, and the ranges of their values are summarized.			

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